

DEVELOPMENT OF A METHOD FOR THE PRODUCTION OF ALUMINUM METAL FOAMS

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ABSTRACT

Metal foam development is being very challenging process due to the problems incurred during the processing. Various methods have been developed since the 1950's but the commercialization of these processes are still not possible, because of the foams obtained are of inconsistent properties, cost of production, non homogeneous distribution of pores. Obtaining the near net shape (NNS) is another problem in the metal foam production. Although lot of problems involved in the development of metal foams, research people has attracted to the metal foams because of its attractive properties like acoustic damping, bomb mitigation, light weight etc. Especially research on developing Al foam has become more because of its potential application in many engineering fields. The attempt has been made in this work to develop a near net shape of Al foam using NaCl as the space holder in the Al matrix casting the molten metal around sand balls. The problems associated in the process and its effect on the density and porosity of the foam were discussed.

KEYWORDS: Al Foams, Density, NaCl, Porosity, Space Holder, Sand Balls

INTRODUCTION

Metals intentionally fabricated with high degree of porosity are called metal foams ^[1]. Metal foam is a cellular structure consisting of a solid metal, usually aluminum, containing a large volume fraction of gas-filled pores ^[2]. Aluminum foams have a good combination of properties such as high specific stiffness, high strength and good energy absorption. These characteristics make aluminum foams a potential material for absorbing impact energy during the crashing of a vehicle either against another vehicle or any obstacle ^[3]. Metal foams are a sub group of cellular metals, usually having polyhedral cells, but shapes may vary in cases where directional solidification creates different morphologies. Metal foams are either open cell, closed cell, or a combination of the two. Open cell foam forms a network of interconnected solid struts. Closed cell foam is made up of a network of adjacent sealed pores, all sharing walls with each other. The difference between the closed and open cell configuration is clearly seen in pores ^[2, 4].

Metal foam production techniques can be generally classified as Liquid route and powder route. It is shown in the Figure 1. Various parameters are involved in the process are responsible for the quality, size and shape of the metal foam to be produced. The parameters involved are different from process to process. Controlling these process parameters is difficult and thus understanding the process concept is difficult, particularly in liquid route controlling process parameters is a big task. Hence the methods developed for the production of metal foams are still in incipient stage. Some of the process parameters which play pivotal role in metal foam production are

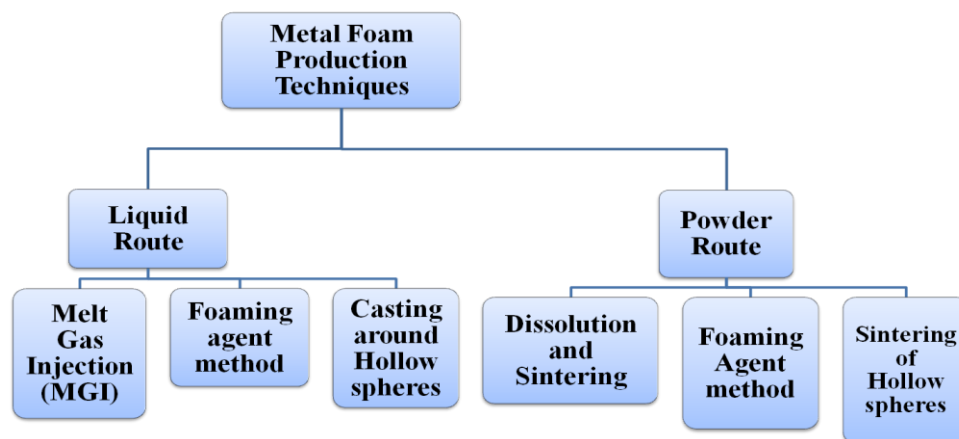


Figure 1: Common Methods Followed for the Producing Al Metal Foams

- Matrix material
- Melt temperature
- Type of foaming agent
- Decomposition Temperature of Foaming agents
- Particle size of the Foaming agent
- Foam stabilizers
- Density of Foam Stabilizers
- Selection of process

By considering the above parameters the method has been developed which is named as Space holder technique. The detail of the experiment is given below in the experimental section.

EXPERIMENTAL PROCEDURE

Aluminum Foam Production Using NaCl Crystal as a Space Holder in the Al Melt

Materials Used

Pure Aluminum as starting material, NaCl crystals as space holder.

Procedure

As in the above method Aluminum (200grams) was melted in a Resistance Furnace and it was heated to 750 °C (to delay the solidification). Then, the melt was poured into a rectangular die of 25mm×25mm×25mm which is made up of Mild Steel. Die was pre-heated in the furnace, which helps in retarding early solidification of aluminum. Die was filled with 40grams of NaCl crystals before pouring the melt into it. Aluminum was poured in to the die containing NaCl. After pouring the melt into the die, NaCl salt crystals start rising in the melt due to density difference. As the solidification progresses and salt crystals get trapped in the melt and also in the solidified aluminum. The casting was taken out of die and treated with hot water. The salt crystals dissolve in water, leaving the pores in space of NaCl crystals. Finally the open cell Aluminum foam was obtained. The foam produced by this method is as shown in figure



Figure 2: Macro Photographs of Aluminum Metal Foam Obtained by Using NaCl Crystals as Space Holder

The experimental observations indicate that the use of NaCl crystal as place holder for the production of aluminum metal foams result in the formation of better quality of metal foams. But even this method is not completely free of foaming difficulties. From the Archimedes principle the density of the prepared samples were measured. The density of foam obtained in this method is about 2.2 to 2.39 g/cc. where the % porosity is calculated by using

$$\% \text{Porosity} = \frac{\rho_{\text{Al}} - \rho_{\text{f}}}{\rho_{\text{Al}}} \times 100 \text{ and it was obtained around 12 to 20\% of the theoretical density of the Aluminum.}$$

Following are some of the problems associated with the use of NaCl crystals for the synthesis of aluminum metal foams.

- Chances of entrapment of un-dissolved NaCl crystals inside the cast components may lead to defective castings with non uniform properties.
- Uniform distribution of NaCl Crystals inside the melt was found to be very difficult.

Experimental observations indicate that the density of NaCl (2.16 g/cc) is much low compare to Al (2.7 g/cc). Therefore, the NaCl particles try to float and agglomerate quickly in the melt. Therefore process improvements are required to produce the Foams using NaCl successfully.

Foam Production by Casting around Sand Balls

It is a manufacturing process by which a liquid material is usually poured into a mold which contains a hollow cavity of the desired shape, and then allowed to solidify. In this method the desired hallow cavity was filled with sand balls. The picture of sand balls prepared is shown in Figure 2. These sand balls were prepared by mixing the mold sand with some extra Bentonite with some moisture. Then small balls were prepared by hand. Prepared balls were placed in an oven to remove the moisture content. The prepared balls were loosely filled inside the cavity and molten metal was poured inside the cavity where the cavity is filled with molten metal and sand balls. After solidification, the casting is allowed for cool to room temperature. Then casting is taken out and sand balls were removed, leaving behind a metal foam structure as shown in Figure 3.

In this process fluidity of the metal plays a vital role. In case of aluminum it is a problem because its fluidity is low and also solidifies quickly, where in depth reaching of molten aluminum inside the mold is very difficult. From the literature is available that this method is suitable for cast iron products. Another problem in this method is that sand inclusion may occur in the product.



Figure 3: Sand Balls



Figure 4: Foam Obtained by Casting around Sand Balls

RESULTS AND DISCUSSIONS

Evaluation of Density of the Al Foam

Foams obtained are in irregular shape and density calculation by normal method is not possible. However it can be calculated by using Archimedes principle.

Measuring Jar (MJ) as shown in figure 5 was used to calculate the density of the Al foam obtained by different routes. Density of the foam was calculated as follows

To Find the Actual Volume of the Foam Specimen

- Water was filled in a MJ for specified amount. E.g. 500ml. it is the initial water level in the MJ.
- Then immerse the foam specimen into the water contained MJ slowly and new level of water is recorded.
- Difference between the initial and final level of water in the MJ, which gives the actual volume (V in cc) of the foam specimen.
- Weigh the foam specimen and its mass (m in grams) is recorded.
- Now the density of foam is calculated as follows.

$$\rho_f = \frac{m}{V} \text{ g/cc}$$



Figure 5: Measuring Jar Used for Volume Calculation

CONCLUSIONS

Aluminum metal foams were synthesized Space Holder (NaCl) technique. Though this method help in the formation of metal foam the quality of the foams produced was not satisfactory. Casting around sand balls helps in achieving better foam structure, but the Al solidifies rapidly and it doesn't flow inside the cavity due to lack of fluidity. This method yields in achieving density of 2.16 g/cc. This method was very helpful and it can be promising method for getting the foam with near net shape. By observing and summarizing the points it can be concluded that processing may be easy to carry out, but controlling the process parameters is very difficult. Hence the production of Al foams in general metal foams is a continuous challenging and innovative process. More experiments and trials are needed to develop a sophisticated method for producing good quality foams at lesser cost, because of the present sophisticated methods available are of very of high cost and also production is not yet commercially approved.

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